Utilizing Petrophysical Attributes to Optimize Performance of a Horizontal Drilling Program*

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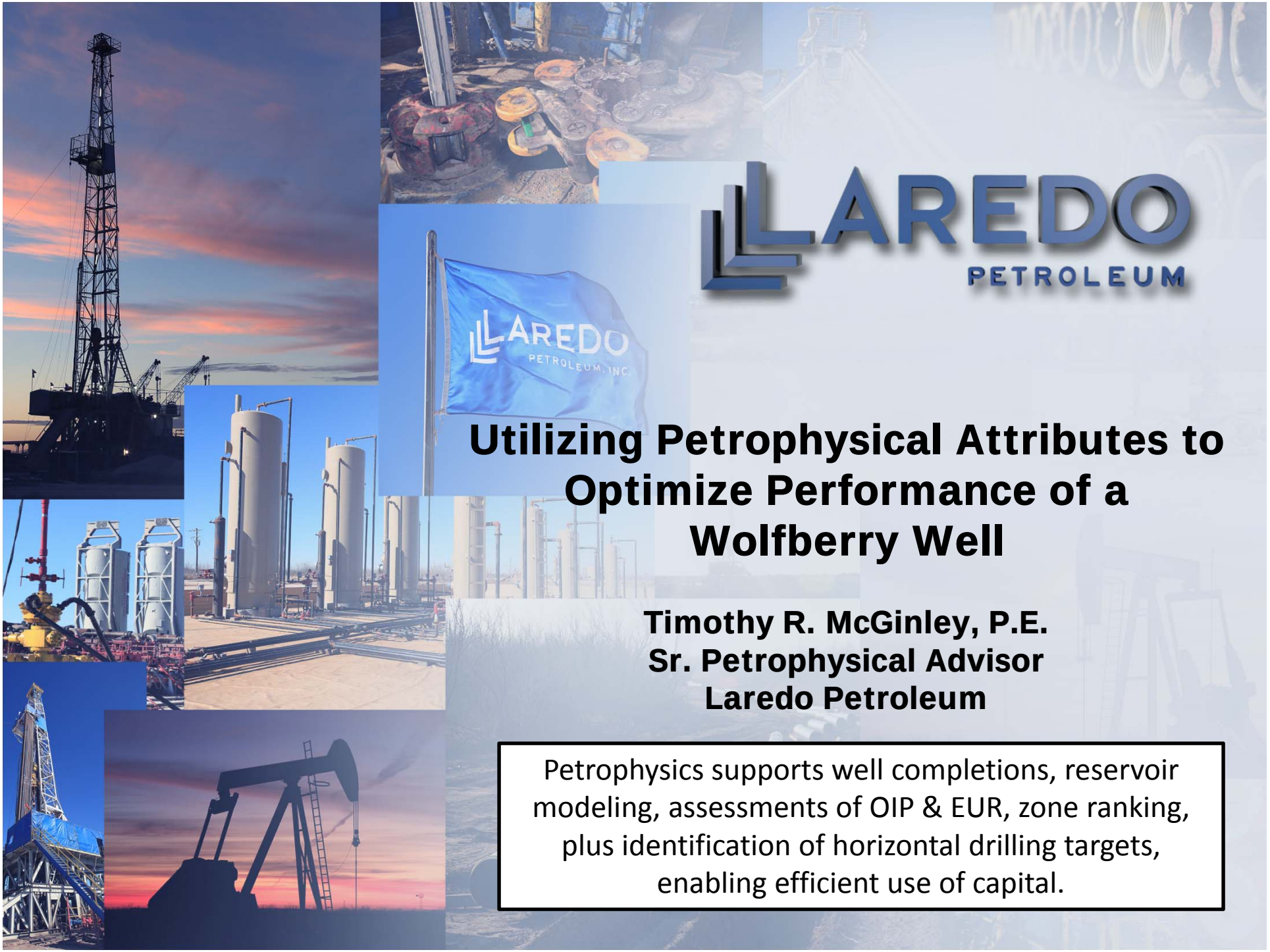
Abstract

Petrophysics enables focused well completions, reservoir modeling, assessments of OIP and EUR, zone ranking, and identification of horizontal drilling landing points, thus facilitating efficient use of capital. A vertical drilling program contributes significantly to the technical database. By Integrating whole and sidewall core data, such as GRI, XRD, and TOC measurements, critical sideboards for the interpretation of wireline logging data can be achieved. Measurements of compressional and shear acoustic data for generation of rock mechanical properties also plays a key role in the petrophysical interpretation.

With 95% coverage of Garden City acreage with 3-D seismic and greater than 50% coverage with high effort proprietary 3D data, Laredo is correlating seismic attributes and petrophysical characteristics to determine regional rock features. With all this technology added to the Laredo tool box, comprehensive analyses are utilized to create a strong horizontal development plan and maximize shareholder value via a growing list of high performing wells.



Utilizing Petrophysical Attributes to Optimize Performance of a Wolfberry Well

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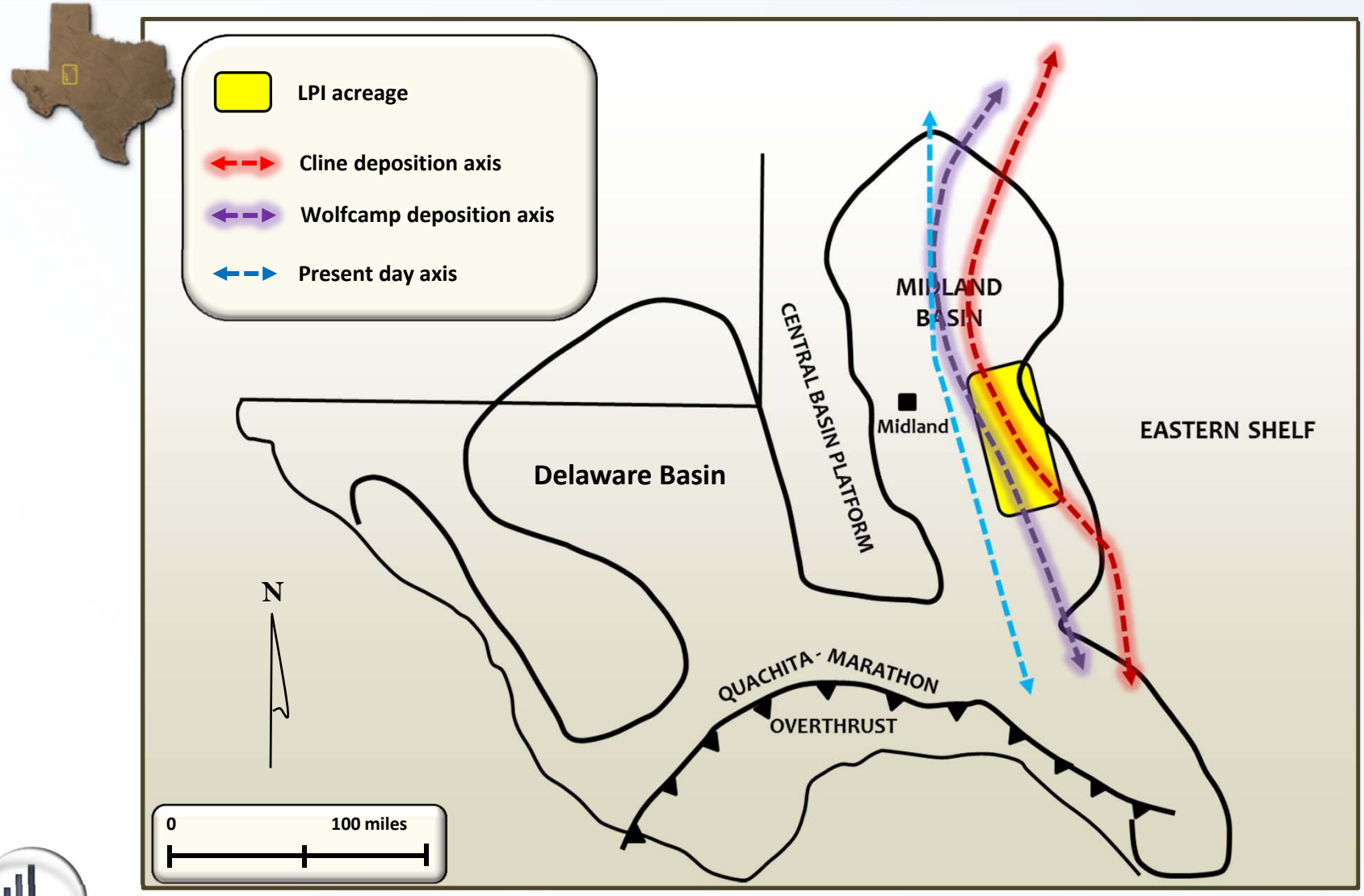
Petrophysics supports well completions, reservoir modeling, assessments of OIP & EUR, zone ranking, plus identification of horizontal drilling targets, enabling efficient use of capital.

Petrophysics Key Points

- **Integration, Integration, and more Integration**
- **Get the correct logging data!**
  - Laterologs will read different than Inductions (50 year issue)
    - *You just might walk away from a discovery well*
  - Minimally Triple Combo…Dipole sonic & FMI very helpful
- **Whole and sidewall core data provide *critical constraints***
  - GRI, XRD processes (always include quality control checks)
  - Shale properties (TOC, gas analyses, etc.)
- **Optimize well placement and completions for efficient hydrocarbon recovery**

Permian Basin: Present Day



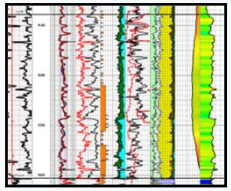
Vertical Program Supports Science Gathering

Vertical Wolfberry program provides science/data for horizontal program tool box

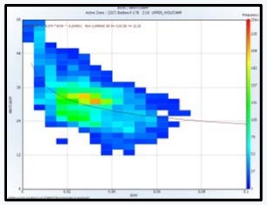
Science Enhances Value

Cores

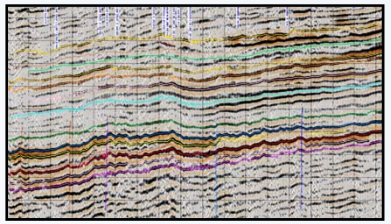
Logs



Reservoir characterization



3D Seismic

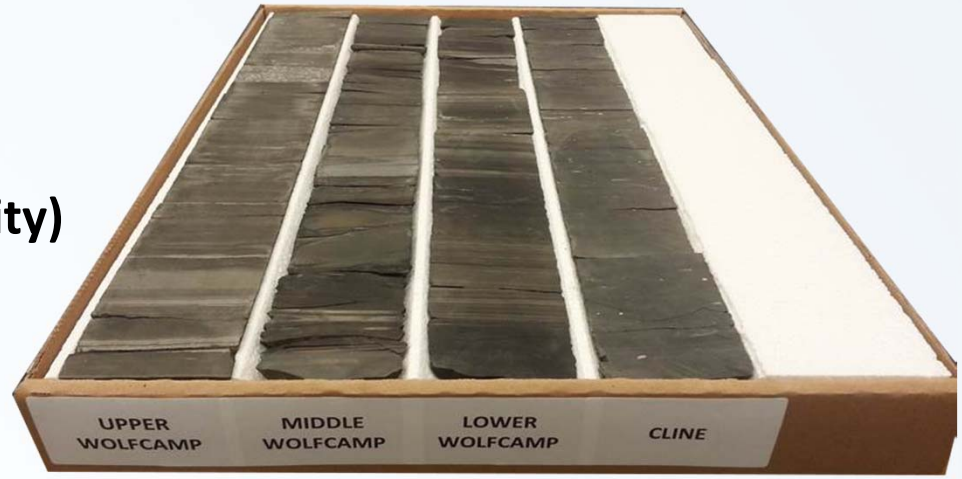


Optimize development plan - maximize shareholder value

Key Shale Rock Play Attributes

Integration of the shale petrophysical attributes has a direct correlation to the performance of a well

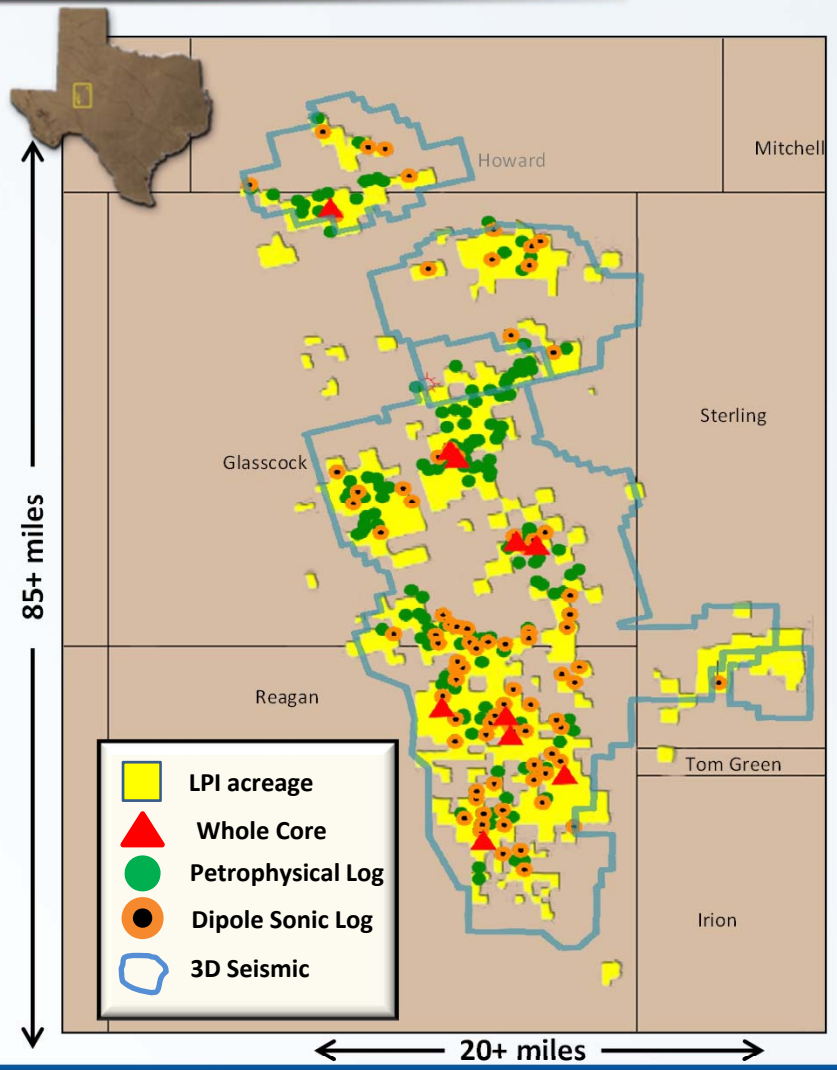
- **Mineralogy (Brittleness)**
- **Porosity/Permeablity (Rock Quality)**
- **Organic Richness (TOC)**
- **Thermal Maturity (Ro)**
- **Burial Depth**



Information ⇨ Insight ⇨ Impact

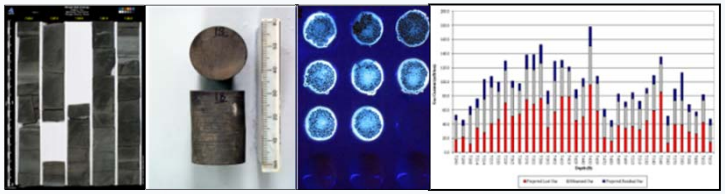
Garden City Data Inventory

- ~3,400' Whole core in objective section
  - 13 Whole core
  - >650 SWC samples
- 34 Single zone tests from objective section (Spraberry to Ellenberger)
- >8,000 Conventional open-hole logs
  - 228 In-house petrophysical logs
  - 96 Dipole sonic logs
  - Fully Core-calibrated
- 774 sq mi 3-D Seismic
  - 95% Coverage of Garden City Acreage
  - >50% of Seismic Inventory is High Quality, Proprietary 3D Data

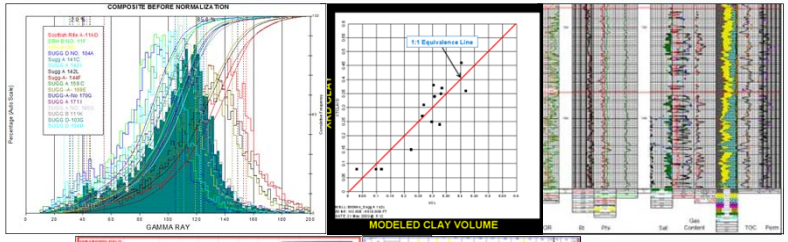


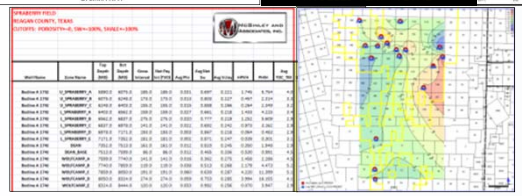
Integration of Core, Petrophysics and Production Data Defines Resource Potential

Comprehensive Core Sampling & Data Analysis
Conventional & Unconventional Reservoir Lithologies

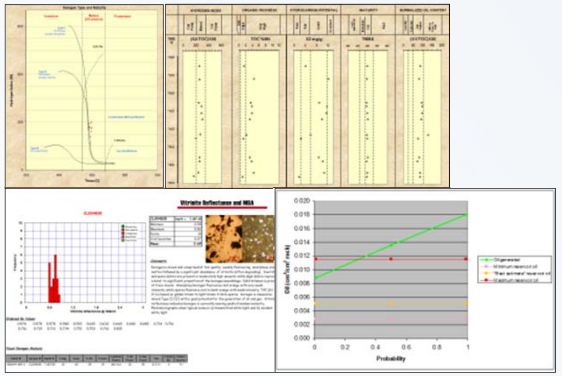


Log Data QC, Statistical Integration of Core and Log Data, Attribute Analysis Computations & Volumetrics





Analysis of Source Rock Geochemistry Data for Maturity, Richness, Burial\Thermal History and HC Volumes Generated



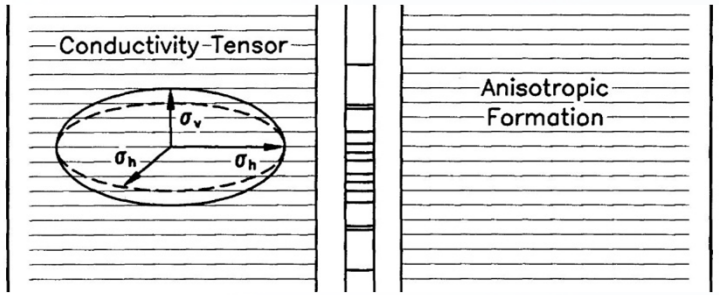
Volumetric Summaries and Zone Rankings

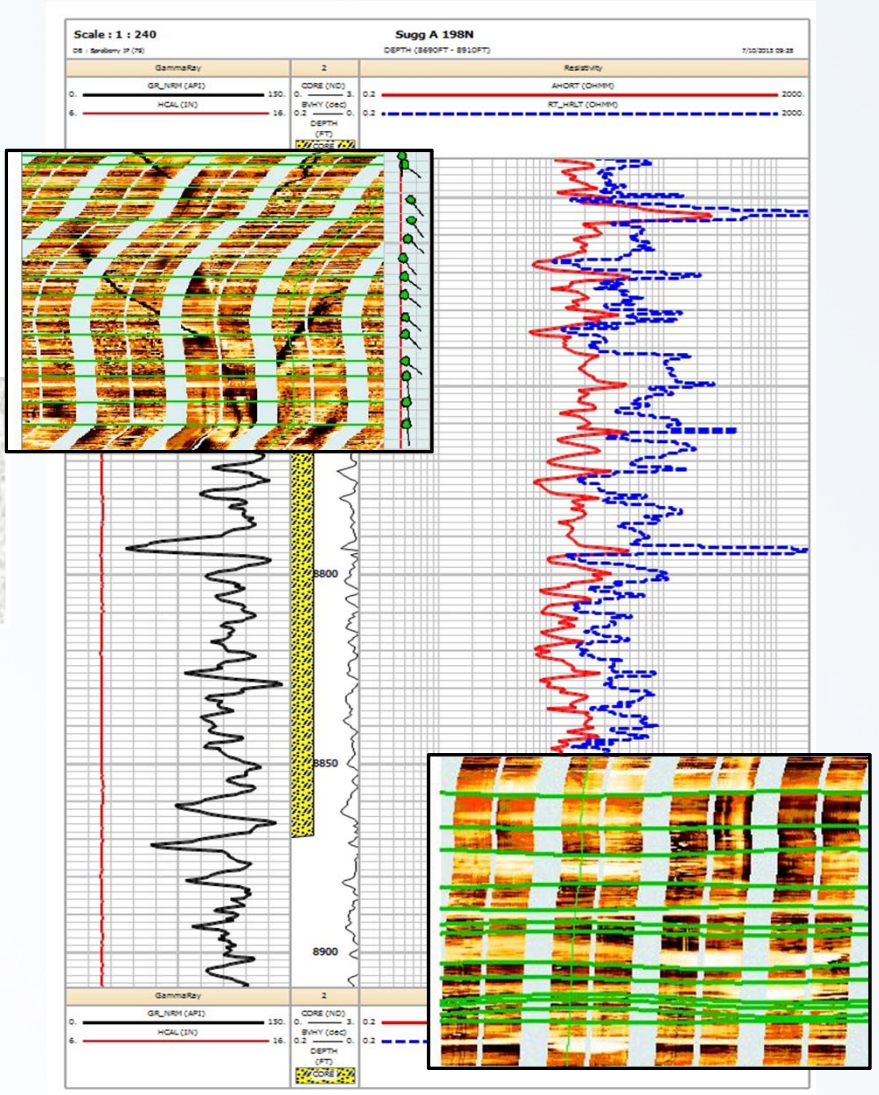
Interval	Reservoir OOIP/40ac	Volume Rank	In-Place STBOE/40ac	# of wells completed in zone
U Spraberry A	865 MBO	4th	898 MBOE	1697
U Spraberry B	461 MBO	8th	479 MBOE	788
U Spraberry C	365 MBO	9th	379 MBOE	737
L Spraberry A	778 MBO	5th	807 MBOE	1616
L Spraberry B	1,186 MBO	1st	1,231 MBOE	2153
L Spraberry C	517 MBO	6th	537 MBOE	1986
L Spraberry D	163 MBO	13th	169 MBOE	1042
L Spraberry E	86 MBO	15th	89 MBOE	986
Dean	310 MBO	11th	321 MBOE	2735
U Wolfcamp	143 MBO	14th	142 MBOE	1648
Wolfcamp A	328 MBO	10th	325 MBOE	1314
Wolfcamp B	517 MBO	7th	512 MBOE	1287
Wolfcamp C	953 MBO	3rd	945 MBOE	1134
Wolfcamp D	1,164 MBO	2nd	1,154 MBOE	572
Wolfcamp E	268 MBO	12th	265 MBOE	206

Induction and Laterolog Resistivity Comparison

LATEROLOG AND INDUCTION TOOLS READ SHALES DIFFERENTLY

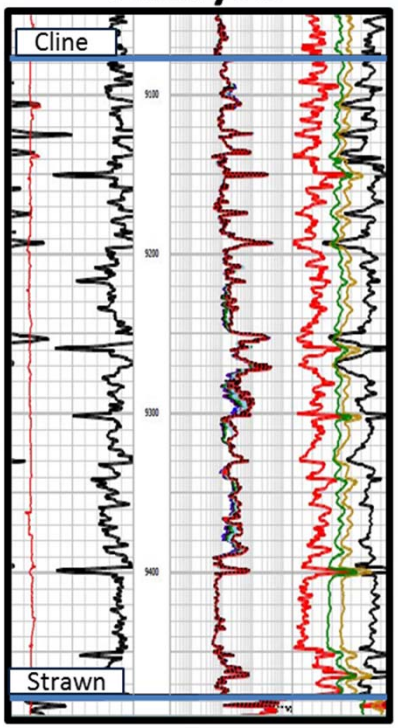
SHALE ALTERATION DUE TO FRESH DRILLING MUD INVALIDATES THE LATEROLOG DATA, COMPOUNDED BY ANISOTROPY AND RESISTIVE CLASTS





Laredo's Proprietary Analysis

Basic Industry Log Analysis



Open-Hole Logs

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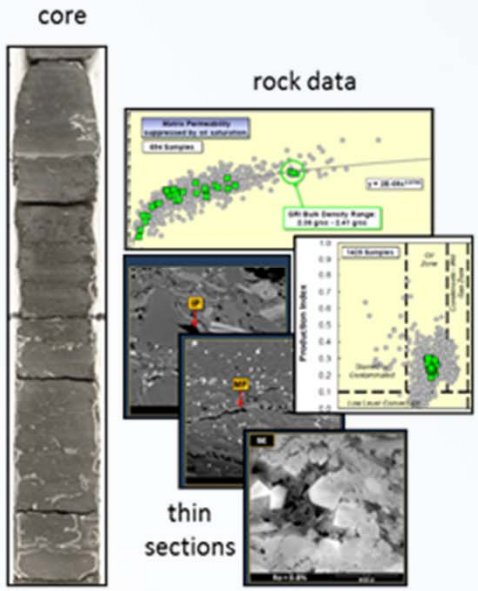
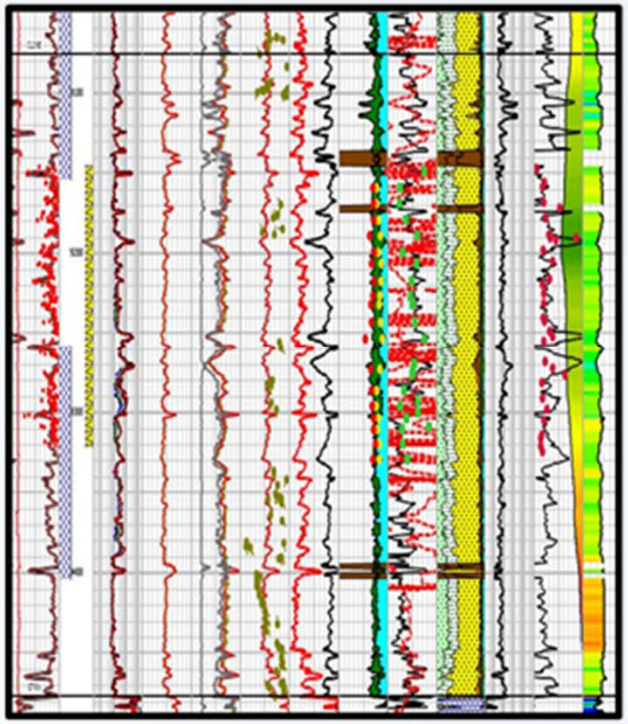
Advanced LPI Proprietary Analysis



Cores / Science

=



LPI Proprietary Analysis

Understanding Fracability is a Key

"Fracability" = brittle shales that hydraulically fracture during completion work the best

ROCK MECHANICS

Calibrated dipole sonic to our data

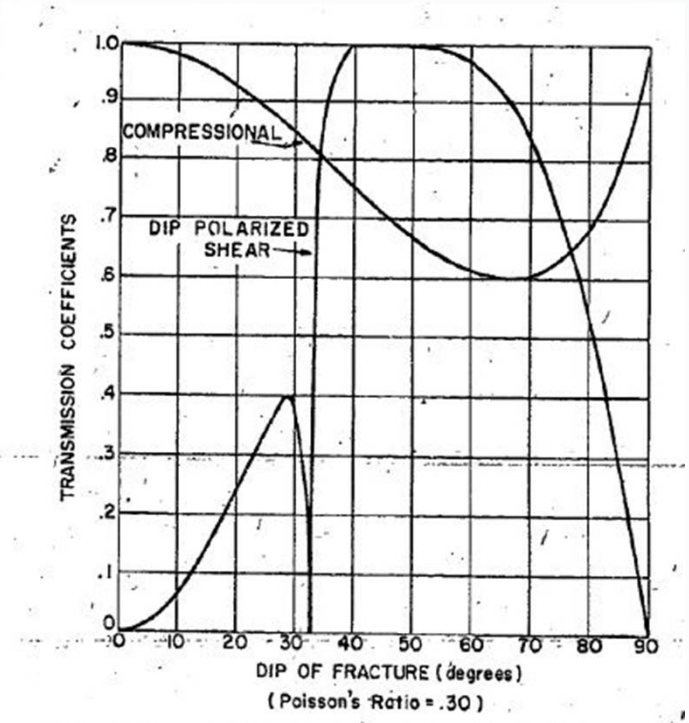
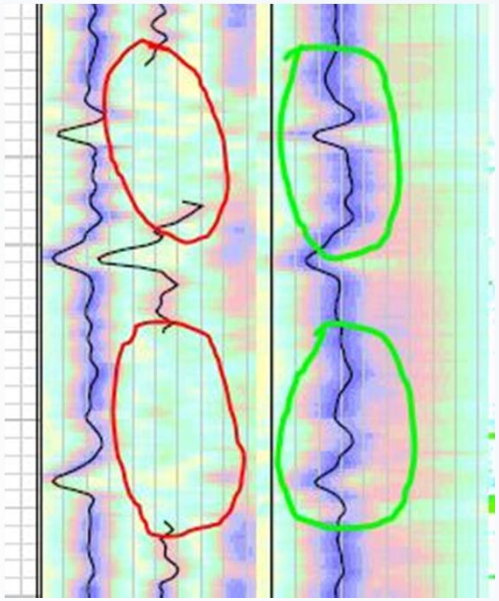


Fig. 6—Calculated curves of transmission coefficients for plane compressional and plane dip-polarized shear waves across an infinitely thin lubricated crack in an infinite medium (Knopoff, et al.).



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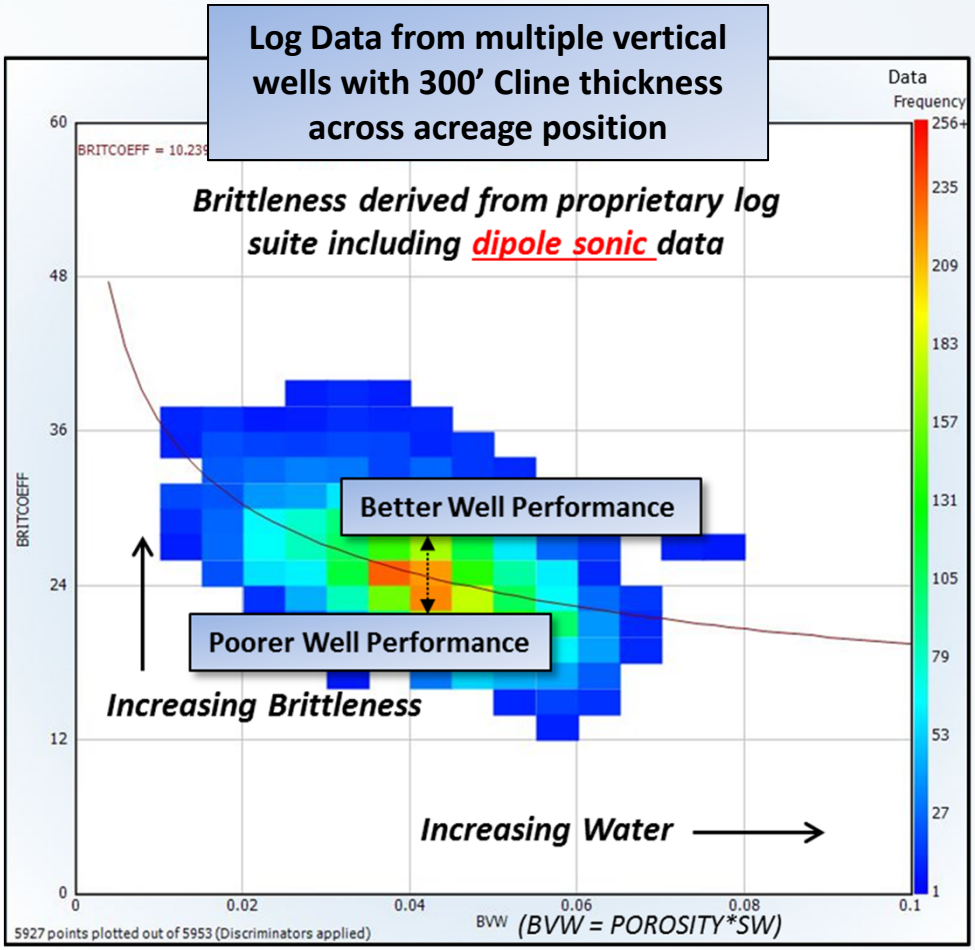
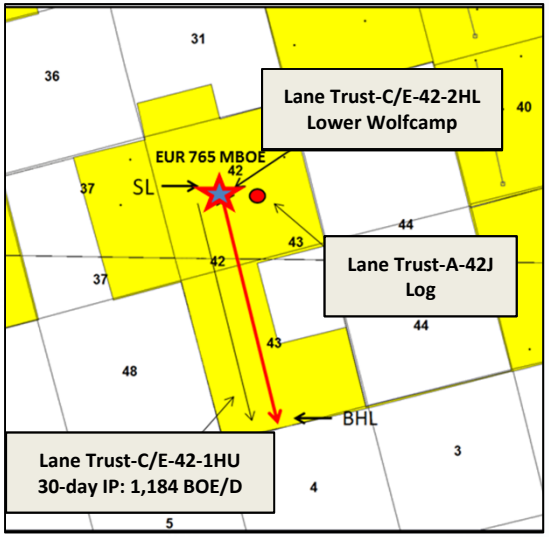
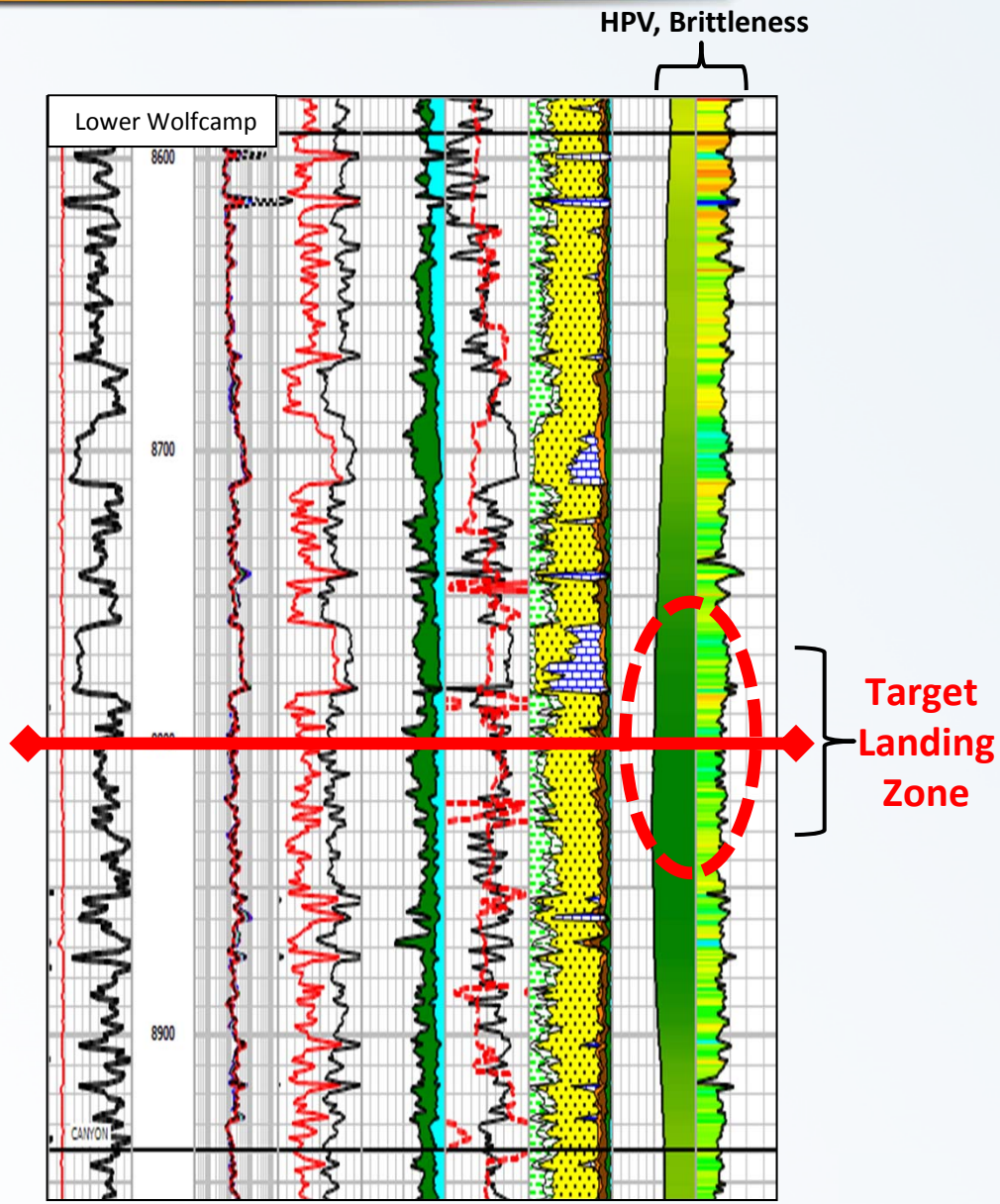


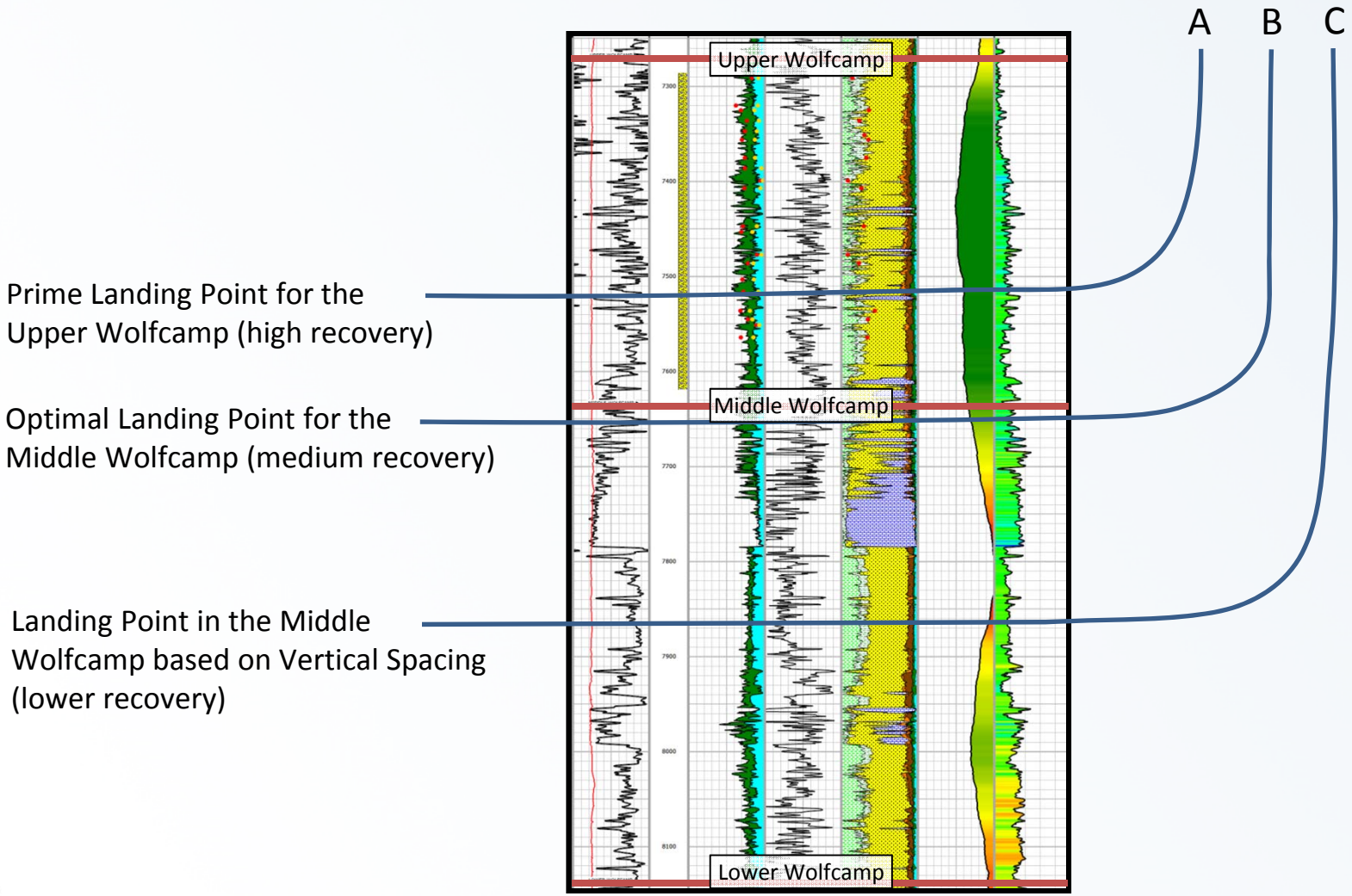
Science Impact to Lane Trust-C/E-42-2HL

- Based on analysis of the advanced log suite
  - Highest HPV in the interval
  - Most brittle rock in the interval
  - Low frac gradient for optimal stimulation
- Landed lateral in Lower Wolfcamp shale
- **Well tested 1,217 BOE/D average 30-day IP**



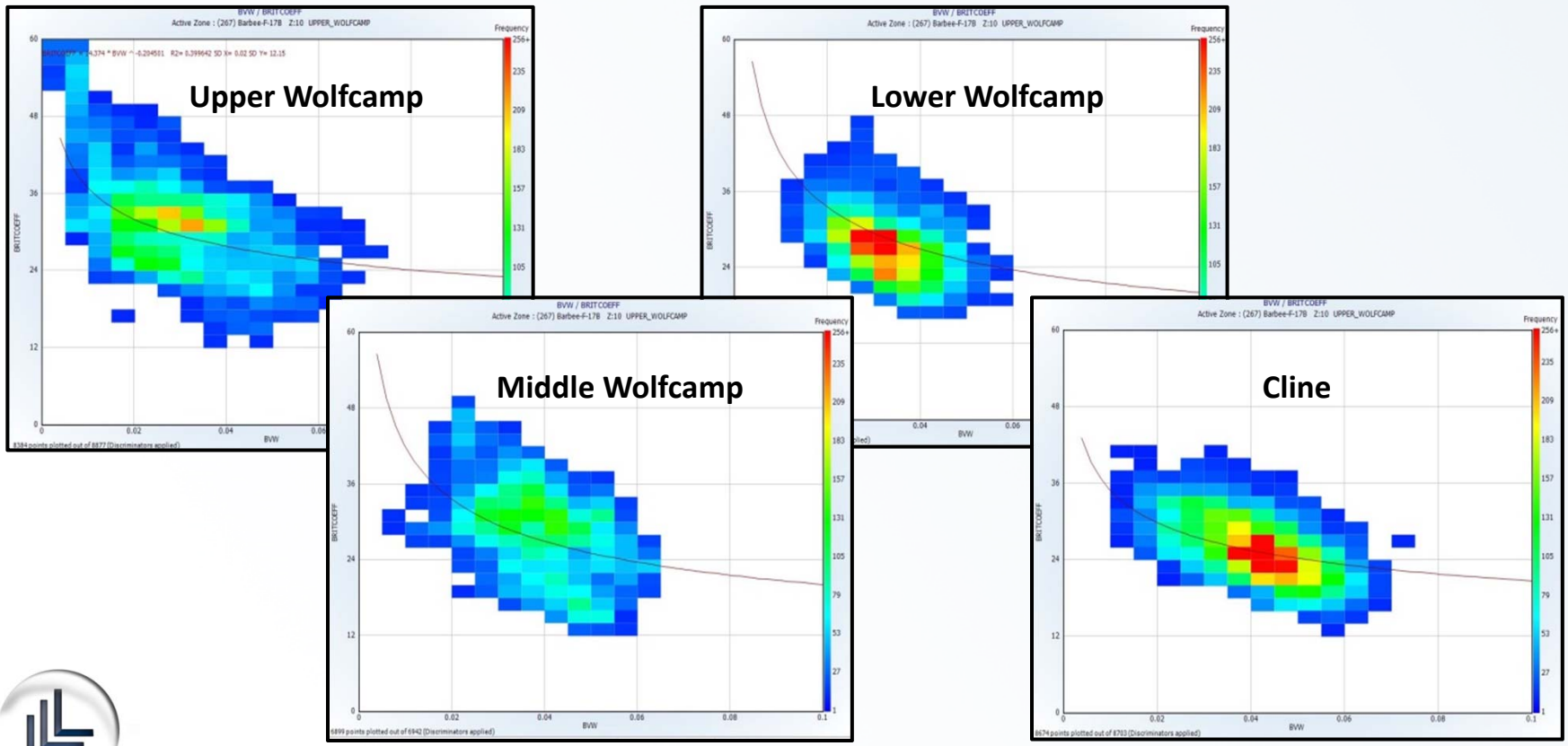


Example: Permian Shale Petrophysics Application to Horizontal Program



Applying Fracability to All Proven Zones

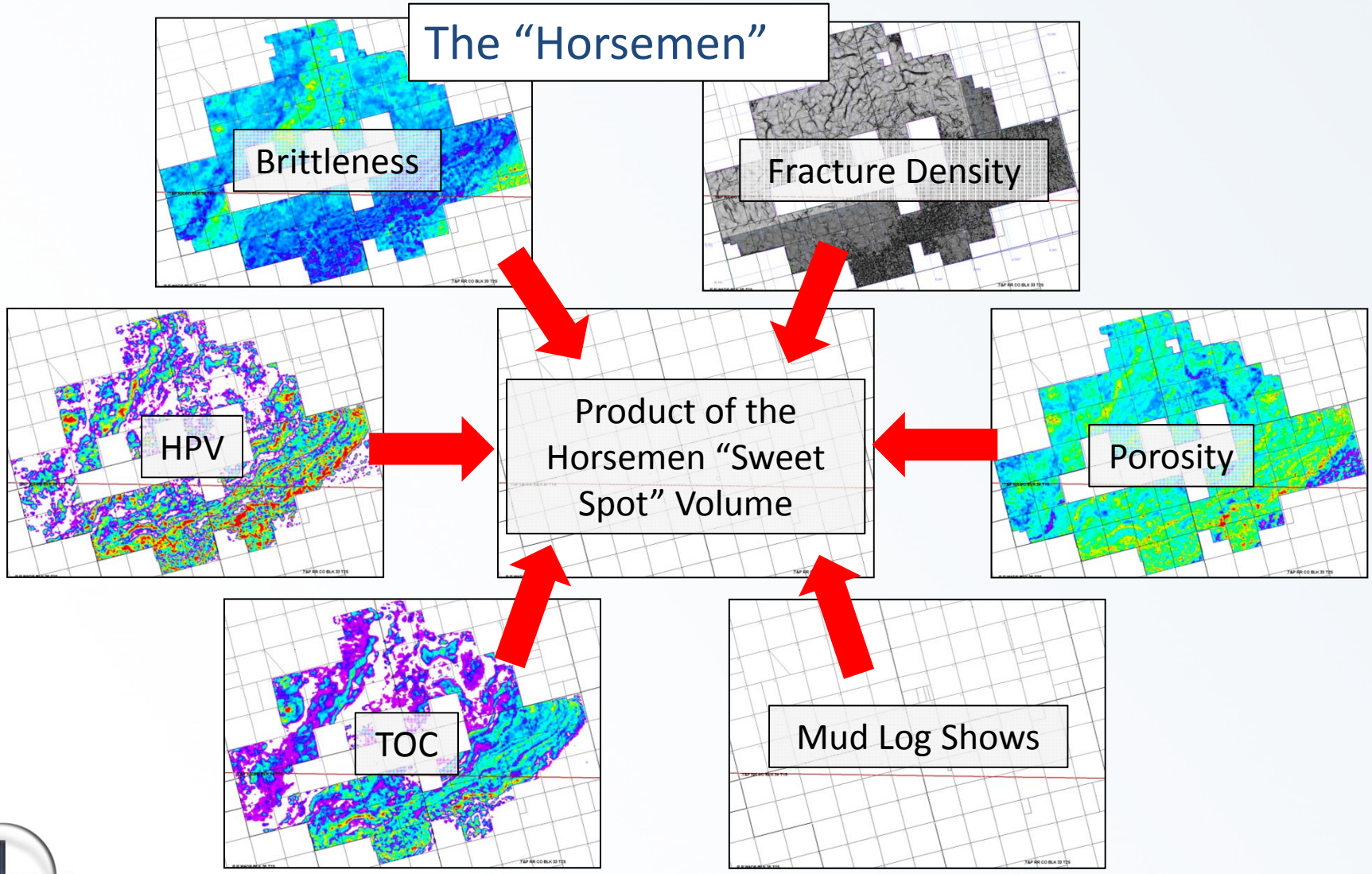
- Log brittleness helps in targeting all four producing horizontal intervals
  - Brittleness is a function of clay and water content
  - Brittle rock targeted in landing laterals
- Brittleness predictions assist in frac design



Brittleness Takeaways

- The role of rock brittleness and bulk volume water, along with other mechanical properties appear very significant
- Map wireline developed mechanical properties
  - Poisson's ratio
  - Young's modulus
  - Brittleness
- Tie seismic expressions to these same mechanical properties
  - Fully describe regional characteristics
- Integrate these data for targeting horizontal wellbore placement and grouping completion stages via horizontal stress measurements

Seismic Expression of Petrophysical Properties



Summary

- Core constraints determined for Wolfcamp, Cline and Atoka-WDFD (***induction logs key to consistency in fresh mud***)
- Refined frac gradient/brittleness model
- Petrophysical presentation for completion design
- Optimum evaluation requires GR /NEUTRON /DENSITY /PE /RES /DIPOLE SONIC to generate mechanical properties
- ***End result is growing list of high performing horizontals***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